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National Inventory of Sources and Emissions of Mercury (1978)

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NATIONAL INVENTORY OF SOURCES AND EMISSIONS OF MERCURY (1978)

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ABSTRACT

Atmospheric emissions of mercury from various Canadian sources have been estimated for 1978. The data presented in this report are summarized in Table 1 and Figures 1 and 2. Total mercury emissions to the atmosphere in 1978 are estimated at 39 855 kg. The largest source of emissions is from base metal recovery, which accounts for 40.8% of the total. Coal combustion accounts for 12.7% and paint application for a further 12%.

This study is an update of a previous inventory and attempts to assess the effectiveness of air-pollution-control regulatory activity in Canada. As a result of a federal regulation for the chlor-alkali industry, emissions have been reduced by 90% in this sector. The chlor-alkali industry has been identified in the previous inventory as the primary source of anthropogenic mercury emissions in Canada. Assumptions made concerning emissions from other sectors are sometimes different from the original study, due to better information, and have therefore affected the quantifying of mercury emitted to the atmosphere from these sectors.

RÉSUMÉ

Les rejets de mercure dans l'atmosphère ont été évalués au Canada pour 1978. Les données du présent rapport sont résumées au tableau 1 et aux figures 1 et 2. En 1978, le dégagement total de mercure dans l'atmosphère se chiffre à 39 855 kg. Ces émissions sont attribuables à la récupération des métaux communs dans la proportion de 40,8%. La combustion de charbon en produit 12,7% et l'application de peinture 12%.

La présente étude constitue la mise à jour d'un inventaire précédent; elle vise à évaluer l'efficacité des mesures antipollution adoptées au Canada. À la suite du règlement fédéral imposé à l'industrie du chlore, les émissions de mercure y ont été réduites de 90%. Dans l'inventaire précédent, cette industrie avait été reconnue comme la principale source de dégagements anthropiques de mercure au Canada. L'évaluation des émissions causées par les autres secteurs repose sur des postulats différents de ceux qu'on trouvait dans la première étude, parce que l'on dispose maintenant de meilleures données; par conséquent, dans ces secteurs,les dégagements de mercure ne sont plus répartis dans les mêmes proportions qu'avant.

TABLE 1 SUMMARY OF MERCURY EMISSIONS BY PROVINCE AND SECTOR, 1978 (kg)

Sector	Province												
	Nfld.	P.E.I.	N.S.	N.B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.	Y-N.W.T.	Total	%
Chlor-Alkali Industry	-	-	226	291	733	364	-	433	-	327	-	2 374	5.96
Dental Amalgams	2	< 1	3	3	23	31	4	3	7	9	-	85	0.21
Electrical Equipment Manufacturing	-	-	-	-	13	5	-	-	-	-	-	18	0.05
Gold Recovery	-	-	-	-	-	26	-	-	-	11	-	37	0.09
Instrumentation	6	1	9	7	66	88	11	10	19	26	1	244	0.61
Agricultural Chemicals	36	b	b	b	257	275	494	c	c	41	-	1 103	2.77
Paint Manufacturing[d]	< 1	< 1	< 1	< 1	16	38	2	< 1	< 1	7	-	65	0.16
Battery Manufacturing	-	-	-	-	-	67	-	-	-	-	-	67	0.17
Pharmaceutical Use	6	1	9	7	64	85	10	9	19	25	1	236	0.59
Paint Application	114	24	172	138	1 297	1 717	210	191	382	510	15	4 770	11.97
Coal Combustion	-	-	222	60	173	2 838	85	640	1 003	21	-	5 042	12.65
Petroleum Combustion	419	b	b	b	801	526	47	42	366	230	4	2 735	6.86
Natural Gas Combustion	-	-	-	-	4	27	3	9	458	16	-	517	1.30
Wood Combustion	8	< 1	16	33	153	87	8	12	31	418	1	767	1.92
Municipal Incineration	-	-	-	-	1 028	437	116	21	-	21	-	1 623	4.07
Sewage Sludge Incineration	-	-	-	-	-	116	-	3	-	5	-	124	0.31
Fluorescent Tube Breakage	80	17	122	98	915	1 212	150	136	269	363	13	3 375	8.47
Thermometer Breakage	8	2	14	12	110	137	18	19	39	43	1	403	1.01
Base Metal Recovery												16 270	40.83
TOTAL[a]	679	45	793	649	5 653	8 376	1 158	1 528	2 593	2 073	36	39 835	
% Total[a]	2.88	0.19	3.36	2.75	23.97	35.51	4.91	6.48	11.00	8.80	0.15		

a Total and % total does not include emissions from base metal recovery in order to maintain individual plant confidentiality.
b Included in total for Newfoundland.
c Included in total for Manitoba.
d Sum of provincial emissions do not add up to national total due to rounding.

Note: Sectors covered in this table do not include those sectors in the text where emissions have been determined as negligible or where activity in that area is non-existent.

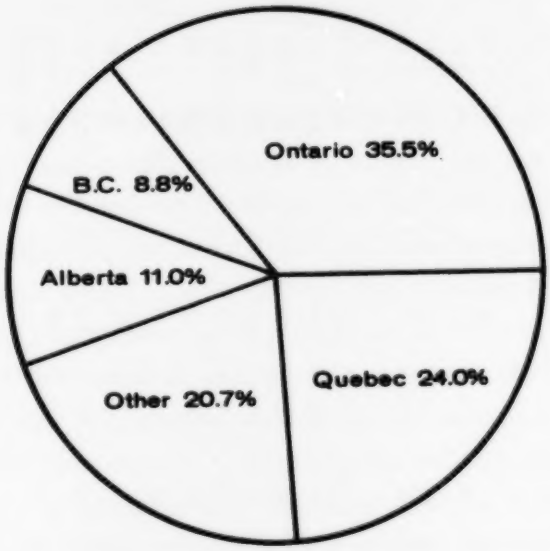

FIGURE 1 PERCENT MERCURY EMITTED BY PROVINCE, 1978*

*Does not include emissions from base metal recovery.

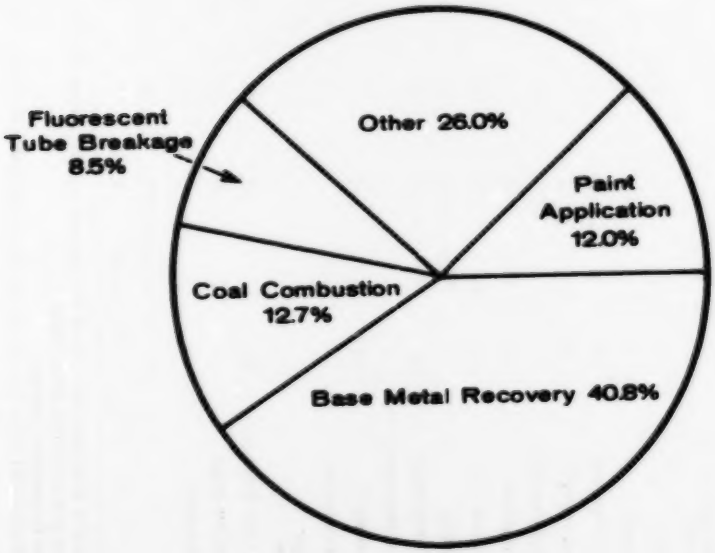

FIGURE 2 PERCENT MERCURY EMITTED BY SOURCE, 1978

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1 INTRODUCTION

1.1 Scope

The objective of this study is to identify the major sources and quantify their emissions of mercury and mercury compounds into the ambient air in Canada for the base year 1978. This study, an update of the inventory prepared for the base year 1970, attempts to assess the impact of regulatory activity in Canada.

Information in this report was obtained from various scientific and technical publications and journals, from government reports, from Canadian industry and through personal contacts. The mercury emissions determined from available data are the best approximations possible and give a good indication of the magnitude of emissions in Canada for 1978.

1.2 Natural Sources of Mercury

Natural processes release mercury into the atmosphere from a variety of sources including soil and crustal degassing, vegetation, marine and lake systems, volcanic and other related activities and forest fires. A more detailed discussion of emissions from natural sources can be found in another Environment Canada report (1).

1.3 Physical and Chemical Properties

Mercury is a silvery white metal that is a liquid under standard conditions. Its unique physical properties combining characteristics of both liquid and metal have led to its widespread use in medicine, science and industry. Some of the physical and chemical properties of mercury are listed in Table 2.

Many mercury compounds, both organic and inorganic, are presently used. All mercury compounds are volatile, and most decompose to mercury vapour. A few, mainly the halides, sublimate without decomposition. Table 3 describes some of the more common mercury compounds in use.

TABLE 2 PHYSICAL AND CHEMICAL PROPERTIES OF MERCURY (2, 3)

Symbol	Hg
Atomic Weight	200.59
Atomic Number	80
State	liquid (at standard conditions)
Melting Point	-38.87 °C
Boiling Point	356.58 °C
Density	13.55 g/cm^3 (20 °C)
Viscosity	1.55 cP (20 °C)
Surface Tension	465 dynes/cm (20 °C)
Thermal Conductivity	0.0201 cal/(S•cm• °C)(20 °C)
Heat of Fusion	2.7 kcal/g
Specific Heat	0.033 cal/g• °C (20 °C)

TABLE 3 SOME MERCURY COMPOUNDS AND THEIR GENERAL USES (3, 4)

Compound	Formula	Uses
Mercurous chloride (calomel)	Hg_2Cl_2	Agriculture, medicine
Mercuric chloride (corrosive sublimate)	$HgCl_2$	Agriculture, medicine, photography
Mercuric cyanide	$Hg(CN)_2$	Medicine
Mercuric iodide	HgI_2	Medicine
Phenylmercuric acetate	$C_6H_5HgOC(O)CH_3$	Agriculture, paints
Mercuric oxide	HgO	Agriculture, paints, batteries
Mercuric sulphide (cinnabar)	HgS	Pigment
Methoxyethylmercuric acetate	$CH_3OC_2H_4HgOC(O)CH_3$	Pulp and paper, agriculture
Ethyl mercuric chloride	C_2H_5HgCl	Agriculture

2 EMISSIONS FROM MERCURY PRODUCTION

2.1 Mercury Mining

There has been no mine output of mercury in Canada since July 1975, when the only mine in operation suspended operations (5).

2.2 Secondary Production

Mercury is no longer recovered from scrap dental amalgams, as was reported in the initial mercury inventory (6). All material is shipped to the United States for processing.

2.3 Distillation of Mercury

For some applications mercury must be commercially distilled prior to use, in order to ensure purity. Impurities tend to form amalgams which float on the mercury surface, thus necessitating distillation.

The quantity of mercury distilled in Canada is limited to two plants, which are to be shut down by 1980 (66). Since the operation is totally enclosed, mercury emissions are assumed to be negligible.

3 EMISSIONS FROM THE USE OF METALLIC MERCURY

3.1 Chlor-Alkali Industry

3.1.1 Process Description. Almost all chlorine is made by electrolysis, principally of sodium chloride (NaCl) brine. The co-product is caustic soda. To preserve the desired products, cells have been developed to prevent mixing. The cell types most widely used are the mercury cell and the diaphragm cell. A third cell type, developed recently, is the membrane cell. Many factors must be considered in determining the preferred cell type for any given circumstance.

The feed material for the mercury cell process is common salt (sodium chloride). The salt passing through the electrolyzer is electrolytically decomposed to sodium and chlorine. The depleted brine leaving the electrolyzer is acidified and air blown to remove dissolved chlorine. It is then neutralized and recycled to the dissolver.

The chlorine formed is about 99% pure. It is dried by cooling and demisting, followed by scrubbing with sulphuric acid. It is then liquefied by cooling and compression. Residual gaseous impurities, containing some uncondensed chlorine, are passed through a tail gas scrubber, where contact with caustic soda (NaOH) solution removes the chlorine.

The sodium formed at the cathode in the electrolyzer combines with the mercury to form sodium amalgam which flows to the denuder, where it comes into contact with water to form caustic soda, hydrogen and mercury. Mercury from the denuder is returned to the electrolyzer. Figure 3 is a flow diagram of a typical process scheme (7).

3.1.2 Emissions. Major emissions of mercury are from the hydrogen stream, cell end-box vent air and cell room ventilation air. The stream emanating from the cell room cannot be reasonably treated due to the high volume involved. Emissions from this source are kept low by good housekeeping. The other two major emission sources are normally treated before being vented to the atmosphere.

Emissions have been calculated on the basis of detailed industry information for these sources (8). Mercury emissions from the use of mercury cells in the chlor-alkali industry are presented in Table 4 by source and in Table 5 on a provincial basis.

3.2 Dental Amalgams

The composition of a typical amalgam alloy is: 68-70% silver, 25% tin, less than 6% copper, less than 2% zinc and less than 3% mercury. Additional mercury is added

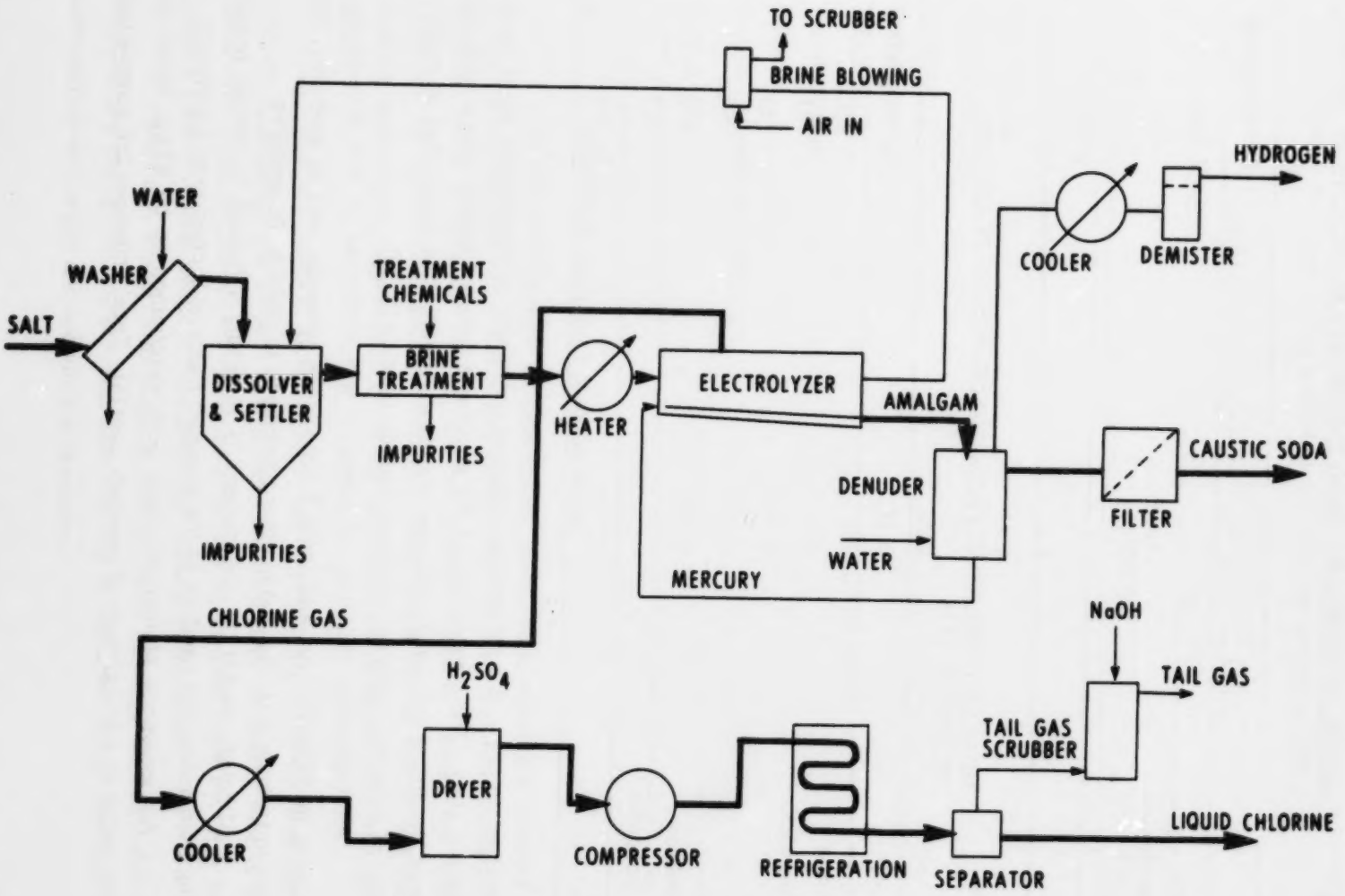

FIGURE 3 **FLOW DIAGRAM, MERCURY CELL PROCESS (7)**

TABLE 4 MERCURY EMISSIONS FROM CHLOR-ALKALI PLANTS BY SOURCE, 1978

Source	Emissions (kg)
Cell room	2 056
Hydrogen stream	215
End-box	103
TOTAL	2 374

TABLE 5 MERCURY EMISSIONS FROM CHLOR-ALKALI PLANTS BY PROVINCE, 1978

Province	Emissions (kg)
Nova Scotia	226
New Brunswick	291
Quebec	733
Ontario	364
Saskatchewan	433
British Columbia	327
TOTAL	2 374

later in order to produce a restoration material containing approximately equal parts of mercury and alloy. The composition of the amalgams does not change appreciably during the life of the filling and weight changes are usually small. The losses that do occur are the result of abrasion, leaching, corrosion and mastication (9, 10).

An estimated 10 000 kg of mercury was consumed in the preparation of restorations in 1978 (9). An additional 8 000 kg was probably used in inventory, filling dentures, in training patterns, and in other procedures to make or fit dentures.

Although danger to the patient is minimal, a hazard to dental personnel resulting from mixing and handling of the amalgam material is considered significant.

Air emissions of mercury have been determined to be 85 kg, based on an emission factor of 8.45 kg/tonne of mercury used (6). Total emissions are summarized in

Table 6. Distribution of emissions is based on population, which is considered to be approximately the same as the dentist distribution per province (68).

TABLE 6 MERCURY EMISSIONS FROM DENTAL USES, 1978

Province	% of population	Mercury Emissions (kg)
Newfoundland	2.4	2
Prince Edward Island	0.5	<1
Nova Scotia	3.6	3
New Brunswick	2.9	3
Quebec	27.2	23
Ontario	36.0	31
Manitoba	4.4	4
Saskatchewan	4.0	3
Alberta	8.0	7
British Columbia & Territories	11.0	9
TOTAL	100.0	85

3.3 Electrical Equipment Manufacturing

In the manufacture of fluorescent tubes, glass tubes are cleaned and filled with phosphor materials in a water suspension. The solution is removed and the tubes are dried to leave a phosphor coating on the interior surface. After the end-caps are attached, the tubes are evacuated through a small glass line in one of the caps. After flushing with argon, approximately 50 mg of mercury are added, and the glass line is sealed.

Mercury vapour street lamps use approximately 90 mg mercury in their production, although the amount is dependent on lamp size. A quartz tube is evacuated, filled with argon and subsequently sealed after the insertion of mercury. It is then placed inside a glass envelope, which is evacuated and filled with nitrogen.

Mercury vapour also plays a role in neon lighting, although the quantities involved are negligible. Green and blue lighting is obtained using mercury vapour in combination with argon and neon at low pressures.

In the manufacture of some batteries, mercury is used in anode production. The types of batteries include carbon/zinc, alkaline MnO_2, zinc chloride, mercury and silver. Small amounts of mercury are amalgamated with zinc to prevent hydrogen overvoltage at the anode. Emissions from the manufacture of battery anodes are discussed in Section 4.3.

Mercury is also used in some types of rectifiers and switches.

Atmospheric losses constitute 0.4% of the total mercury handled (16). Emissions have been determined for fluorescent tubes and mercury vapour lamps.

Table 7 summarizes these emissions.

TABLE 7 MERCURY EMISSIONS FROM ELECTRICAL EQUIPMENT MANUFACTURING, 1978

Province	Emissions (kg)
Ontario	5
Quebec	13
TOTAL	18

3.4 Gold Recovery

Gold can be recovered from the ore by a process known as barrel amalgamation (11, 12). Prior to amalgamation, the pulp (concentrate slurry) is subjected to gravity separation in order to divide it into gold bearing and rock forming mineral components. The gold concentrates and a quantity of mercury are then loaded into a steel barrel, which is rotated. Upon discharge, the load from the amalgamating barrel is again subjected to gravity separation, with the heavier amalgam going to a retort and the lighter fraction containing rock and/or metallic sulphide minerals going either to tailings or to a cyanidation or flotation circuit. The mercury in the amalgam is vapourized in the retort and the remaining "sponge" gold forwarded to a refining furnace. The vapourized mercury is condensed and recycled to the amalgamating barrel.

Theoretically, all of the mercury is recovered and recycled. However, variable quantities can be lost during milling and retorting. The mercury lost in the form of vapour from the retort enters the atmosphere. Up to 10% of the total mercury added can be emitted to the atmosphere (13, 61). Based on this assumption total emissions of

37 kg have been estimated, of which 26 kg are emitted in Ontario and the remaining 11 kg in British Columbia. There are other smaller users (e.g., placer mining operations) whose mercury consumption figures have not been reported.

3.5 Pharmaceutical Manufacturing

Numerous mercury compounds are produced for use in medicines such as antiseptics or diuretics (e.g. mercurochrome, mercurophen). No data are available on the quantity of mercury being used by the pharmaceutical industry. It can be assumed, however, that emissions to the atmosphere are negligible, due to reactions being carried out in closed reactors (16).

3.6 Mercury Compound Production

Mercury compounds are used in agriculture, paint manufacture and battery manufacturing. Minimal quantities of mercury are being used in the manufacture of these compounds in Canada. In the manufacture of paints, however, mercury is used in the production of phenylmercuric acetate and phenylmercuric oleate. In general, emissions data are not available.

3.7 Instrumentation

Metallic mercury is an important part of many industrial and scientific instruments. Several are listed in Table 8.

TABLE 8 INSTRUMENTS USING MERCURY (14, 15)

Instrument	Use
Thermometer	Temperature measurement
Barometer	Atmospheric pressure measurement
Manometer	Pressure measurement
Coulter counter	Red blood cell count
Scholander gas analyzer	Gas analysis
Polarograph	Electrolytic analysis
Diffusion vacuum pump	Vacuum systems

Emissions from these instruments result from their operation and during cleaning and refilling. The losses are in the form of mercury vapour. Assuming a 5% inventory loss through spillage, etc. and an annual replenishing of stock of 1 218 kg (57), total usage amounts to 24 367 kg. Mercury emissions, estimated on the basis of a 1% loss to the atmosphere (61), are calculated to be 244 kg. Provincial estimates are based on population (34) and are shown in Table 9.

TABLE 9 MERCURY EMISSIONS FROM INSTRUMENTS, 1978

Province	% of population	Emissions (kg)
Newfoundland	2.4	6
Prince Edward Island	0.5	1
Nova Scotia	3.6	9
New Brunswick	2.9	7
Quebec	27.2	66
Ontario	36.0	88
Manitoba	4.4	11
Saskatchewan	4.0	10
Alberta	8.0	19
British Columbia	10.7	26
Yukon - N.W.T.	0.3	1
TOTAL	100.0	244

4 EMISSIONS FROM THE USE OF MERCURY COMPOUNDS

4.1 Agricultural Chemicals

Mercury compounds have been found to be effective in the treatment of various plant diseases. The products presently registered with Agriculture Canada (17) are: mercuric chloride, mercurous chloride, phenylmercuric acetate, phenylmercuric lactate and phenylmercuric oleate. They can be found in either all or some of the following forms: granular, dust, wettable powder, suspension or solution. Table 10 lists the uses of mercury-based products now considered acceptable for registration.

TABLE 10 USES OF MERCURIAL COMPOUNDS IN AGRICULTURE* (18)

Use	
Turf	- fungal disease control
Apple	- post-infection spray for the control of apple scab (emergency use)
Blueberry highbush	- control of Godronia stem canker
Douglas fir, pine, hemlock	- treatment of lumber for the control of sapstain and moulds
Wood product, rope and fabric	- rot prevention
Beet, cabbage, chard, cucumber, sweetpea, tomato, turnip and zinnia	- seed treatment for control of bacterial diseases

* Only products for use in treatment of turf, apple and douglas fir, pine and hemlock have been registered to date.

Atmospheric emissions will result from the loss of mercury compounds during application and mercury vapour released from the foliage, fruit or soil surfaces. All mercury contained in fungicides will eventually either be released to the atmosphere or be washed into the soil. Assuming that 50% of the mercury contained in fungicides eventually enters the atmosphere (16), and that the compounds employed have mercury contents based on their respective molecular weights, emissions from agricultural chemicals are 1 103 kg. Table 11 summarizes these results.

TABLE 11 MERCURY EMISSIONS FROM AGRICULTURAL CHEMICALS, 1978

Region	Emissions (kg)
Maritimes	36
Quebec	257
Ontario	275
Prairies	494
British Columbia	41
TOTAL	1 103

4.2 Paint Manufacturing

Organomercurials are employed as preservatives in aqueous emulsion paints at low levels (0.005 - 0.06%) to avoid spoilage in the can, and at slightly higher levels in emulsion and oleoresinous paints to prolong the resistance of the applied film to mildew attack. Phenylmercuric acetate and phenylmercuric oleate are the major compounds used. Mercuric sulphide, used for pigment purposes and mercuric oxide, which could be used as a pigment, are the major inorganic compounds consumed.

Approximately 20 tonnes of mercury were used mainly as fungicide in 1978, in the form of phenylmercuric acetate or phenylmercuric oleate (62). Atmospheric emissions were estimated to be 0.35% of the total mercury used (6). Total emissions of 65 kg, were estimated based on total value of shipments in 1978 (35), and are summarized on a provincial basis in Table 12.

4.3 Battery Manufacturing

Mercuric oxide, when combined with a zinc anode, produces the following overall reaction in a mercury battery:

$$HgO + Zn \rightarrow ZnO + Hg$$

The metallic mercury reaction product is retained in the battery by a double steel case.

Total mercury used in the manufacture of batteries (i.e. anode and cathode) in 1978 was 16 832 kg (57). Emissions from manufacturing, assumed to be 0.4% of the total

TABLE 12 MERCURY EMISSIONS FROM PAINT MANUFACTURING, 1978

Province	Value of Shipments ($ x 10^3)	Percent (%)	Emissions (kg)
Newfoundland	2 768[a]	0.5	< 1
Prince Edward Island	2 768[a]	0.5	< 1
Nova Scotia	2 768[a]	0.5	< 1
New Brunswick	2 768[a]	0.5	< 1
Quebec	139 277	23.9	16
Ontario	341 802	58.7	38
Manitoba	19 786	3.4	2
Saskatchewan	2 768[a]	0.5	< 1
Alberta	3 693	0.6	< 1
British Columbia	63 826	10.9	7
TOTAL	582 224	100.0	65

[a] Value of shipments for these provinces were not given. Values have been calculated based on the number of plants in each province.

mercury handled, are discharged from the operation's ventilating system (16). Total emissions from the manufacturing of batteries are estimated to be 67 kg.

4.4 Pharmaceutical Use

Major mercury compound pharmaceuticals in use are antiseptics, ointments and diuretics. Several of the compounds presently being consumed are listed in Table 13.

During use of the various products the mercury is fully expended and enters the environment as a contaminant, partially as an emission into the atmosphere. Mercury contained in diuretics is emitted to water, and very little, if any, into the atmosphere. Mercurials in antiseptics are emitted partially to water and partially into the atmosphere. Mercurials present in skin preparations and ointments vapourize to some extent, thus becoming an atmospheric contaminant. Mercury added to soaps and face creams as a preservative will also evaporate.

Assuming that emissions due to the use of diuretics are negligible, and that 0.2 kg of each kg of mercury contained in antiseptics, skin preparations and preservatives, is emitted to the atmosphere (16), total emissions are estimated at 236 kg

TABLE 13 MERCURY PHARMACEUTICALS (19, 20, 21)

Compound	Use
Merbromin (mercurochrome)	Antiseptic, skin sterilization before surgery
Mercuric chloride ammoniated	Parasiticide, skin bleach
Mercuric oxide yellow	Opthalmic ointment
Blue ointment (mercury)	Skin preparation
Nitromersol	Antiseptic
Merthiolate (thimerosal)	Antiseptic, skin sterilization before surgery
Mercaptomerin (thiomerin)	Diuretic
Chlormerodrin	Diuretic

TABLE 14 MERCURY EMISSIONS FROM PHARMACEUTICAL USE, 1978

Province	% of population	Emissions (kg)
Newfoundland	2.4	6
Prince Edward Island	0.5	1
Nova Scotia	3.6	9
New Brunswick	2.9	7
Quebec	27.2	64
Ontario	36.0	85
Manitoba	4.4	10
Saskatchewan	4.0	9
Alberta	8.0	19
British Columbia	10.7	25
Yukon - N.W.T.	0.3	1
TOTAL	100.0	236

(based on consumption of 0.27 tonne of mercury in diuretics and 1.18 tonne of mercury in other preparations (6)). Emissions are summarized in Table 14 according to population.

4.5 Pulp and Paper Industry

Mercurial fungicides, such as phenylmercuric acetate, methoxyethylmercuric acetate and diphenylmercuric ammonium propionate have been used to control the growth of microorganisms during pulp and paper manufacture. However, there are no manufacturers using any of these compounds in Canada at present (22).

4.6 Catalysts

Organic mercury compounds can be used in the production of various polymer products. Mercury molecules are dense and if covered by a liquid, diffusion into the atmosphere is slight during the reaction period. Little is known as to the quantity of mercury compounds being used as catalysts in Canada at present. Losses are therefore considered to be negligible.

5 INADVERTENT MERCURY EMISSIONS

Emissions from sources not directly involved with the consumption of mercury and its compounds are estimated in this section.

5.1 Paint Application

As paints are applied, mercury contained in the paint volatilizes, resulting in relatively high losses. As time passes, these levels are reduced but emissions of mercury still occur. Losses of mercury from paints containing phenylmercuric acetate have been measured. Test panels placed indoors were found to lose 20-60% within 250 days, whereas outdoor panels were found to lose 80-100% of their mercury within 20 days. The greater rates of loss from outdoor exposure were thought to be the result of leaching in heavy rainfalls and increased volatilization due to greater air circulation (56, 64, 65).

Since paints containing mercury have successfully protected painted surfaces against fungi for more than three years (63), Broome and Lowrey (67), have postulated that the apparent contradiction of high losses and yet-enduring function of mercurials in paints was due to the substrate used. They also concluded that "much of the mercury in the paint migrated into the wood quickly, perhaps even while the paint was wet".

Based on these findings, we can assume that only a relatively small fraction of the total mercury contained in the paint is emitted to the atmosphere. Assuming that this figure is 25%, emissions have been estimated at 4 770 kg for 1978. They are summarized in Table 15 on a provincial basis (prorated by population) (34).

It should be noted that in 1979, use of mercurials as fungicide for interior paints was curtailed under the Pest Control Products Act administered by Agriculture Canada (17). Registration for their use is required under this Act.

5.2 Combustion Processes

5.2.1 Coal Combustion. Mercury content of coals used in Canada vary from between less than 0.1 ppm for bituminous and sub-bituminous coal from British Columbia and Alberta, to 1.2 ppm for New Brunswick coal (26). Imported coal had an average mercury content of 0.2 ppm.

Combustion studies have shown that 90% of the mercury in the coal was released as a vapour and 10% remained either in the furnace residual ash or in the precipitator ash (23, 24, 25).

TABLE 15 MERCURY EMISSIONS FROM PAINT APPLICATION, 1978

Province	% of population	Emissions (kg)
Newfoundland	2.4	114
Prince Edward Island	0.5	24
Nova Scotia	3.6	172
New Brunswick	2.9	138
Quebec	27.2	1 297
Ontario	36.0	1 717
Manitoba	4.4	210
Saskatchewan	4.0	191
Alberta	8.0	382
British Columbia	10.7	510
Yukon - N.W.T.	0.3	15
TOTAL	100.0	4 770

Coal consumption data on a provincial basis for various sectors were obtained from Statistics Canada publications (27, 28). Assuming various mercury content levels for each province depending on the use of the coal, emissions were calculated to be 5 042 kg. Due to the uncertainty as to when mercury is released during the manufacture and use of metallurgical coke, emissions from both sources are included here. Table 16 summarizes emissions based on use and Table 17 lists emissions by province.

5.2.2 Petroleum Combustion. Trace amounts of mercury are found in crude petroleum. Several views as to what happens to this mercury during refining have been reported (29, 30, 31). On one side, mercury is believed to become concentrated in the heavier oil fractions, while another view states a tendency towards the lighter fractions.

Mercury contents of various crude oils are listed in Table 18.

Due to the unsubstantiated data available with respect to mercury content in products of refining, an estimate of mercury emissions from petroleum combustion has been determined from the mercury content of crude oil. An average mercury content of 30 ppb in crude oil has been assumed.

TABLE 16 MERCURY EMISSIONS FROM COAL UTILIZATION, 1978

Use	Emissions (kg)
Thermal power plants	3 461
Manufacture and consumption of metallurgical coke	1 240
Other	341
TOTAL	5 042

TABLE 17 MERCURY EMISSIONS FROM COAL UTILIZATION, BY PROVINCE, 1978

Province	Emissions (kg)
Newfoundland	-
Prince Edward Island	-
Nova Scotia	222
New Brunswick	60
Quebec	173
Ontario	2 838
Manitoba	85
Saskatchewan	640
Alberta	1 003
British Columbia	21
TOTAL	5 042

TABLE 18 MERCURY CONTENT OF CRUDE OIL (29)

Source	Mercury Content (ppb)
United States	23 - 77
Middle East	3 - 54
Venezuela	6 - 53
Canada	21 - 32

Statistics Canada provides data on the quantity of crude oil delivered to the respective provincial refineries (32). Total emissions from this sector are 2 735 kg and are summarized in Table 19.

TABLE 19 MERCURY EMISSIONS FROM PETROLEUM COMBUSTION, 1978*

Province/Region	Emissions (kg)
Atlantic	419
Quebec	801
Ontario	826
Manitoba	47
Saskatchewan	42
Alberta	366
British Columbia	230
N.W.T.	4
TOTAL	2 735

* Emissions have not been determined based on consumption of final refined products due to lack of data. It has thus been assumed that all mercury in crude oil is transferred to the refined products.

5.2.3 Natural Gas Combustion. Atmospheric emissions will only occur during gas combustion and not during gas purification (33). A mercury content of Alberta natural gas of 1.6 $\mu g/m^3$ for raw gas and 0.028 g/m^3 for condensates (33), were combined with natural gas consumption figures (32, 36) to obtain emissions of 517 kg. The emissions are summarized in Table 20.

5.2.4 Wood Combustion. Trace amounts of mercury in wood, estimated at 0.05 ppm (39), will vapourize during combustion. Forest fire emissions have been estimated in another report (1), while slash burning operations and wigwam burners used in the disposal of sawmill wastes, are determined here. The amount of slash burned and wood residue incinerated have been calculated from a previous methodology (37) and Statistics Canada information (38). Emissions are summarized in Table 21.

TABLE 20 MERCURY EMISSIONS FROM NATURAL GAS COMBUSTION, 1978

Province	Emissions (kg)
Quebec	4
Ontario	27
Manitoba	3
Saskatchewan	9
Alberta	458
British Columbia	16
TOTAL	517

TABLE 21 MERCURY EMISSIONS FROM WOOD COMBUSTION, 1978

Province	Slash Burning	Wigwam Burners Emissions (kg)	Total
Newfoundland	7	1	8
Prince Edward Island	< 1	< 1	< 1
Nova Scotia	13	3	16
New Brunswick	27	6	33
Quebec	107	46	153
Ontario	64	23	87
Manitoba	6	2	8
Saskatchewan	9	3	12
Alberta	21	10	31
British Columbia	237	181	418
Yukon - N.W.T.	1	< 1	1
TOTAL	492	275	767

5.3 Waste Disposal

Mercury contained in manufactured products may be released during their disposal. The sources considered in this section include municipal incineration, sewage sludge incineration and other miscellaneous waste disposal sources.

5.3.1 Municipal Incineration. Many of the materials found in municipal refuse are known to contain trace quantities of mercury. Typical composition of municipal refuse is given in Table 22 (44). Data available on the mercury content of stack gases from incinerators show that it ranges from 0.7 to 3 ppm Hg (40, 41, 42). An average concentration of 1.2 ppm Hg was assumed, along with the assumption that all mercury is emitted as vapour during incineration. Actual emissions were obtained from two Quebec incinerators (43). The quantities of municipal refuse burned were obtained from Environment Canada's regional offices (43). Emissions are summarized in Table 23.

TABLE 22 TYPICAL MUNICIPAL REFUSE COMPOSITION

Component	Percentage
Paper	
Kraft Paper	10.14
Newsprint	9.66
Fine Paper	6.18
Other Paper	16.31
Glass	6.72
Ferrous Metals	6.31
Non-Ferrous Metals	0.65
Plastics	5.47
Ceramics Rubble	1.90
Lumber	4.08
Putrescible	20.65
Textiles, Leather, Rubber	4.64
Yard Wastes Brush	5.31
Fines	1.41
Petroleum Chemical Mix	0.57
TOTAL	100.0

5.3.2 Sewage Sludge Incineration. Trace amounts of mercury have been measured in sewage sludges. Several of the studies undertaken are given in Table 24. An average

TABLE 23 MERCURY EMISSIONS FROM MUNICIPAL INCINERATION, 1978

Province	Emissions (kg)
Quebec	1 028
Ontario	437
Manitoba	116
Saskatchewan	21
British Columbia	21
TOTAL	1 623

mercury content in sewage sludge of 5 ppm and an emission factor of 2 g/tonne of sludge incinerated have been assumed (50, 51). Emissions are calculated using throughput data from Environment Canada's regional offices (43). Total emissions from sewage sludge incineration are given in Table 25.

TABLE 24 MERCURY CONTENT OF SEWAGE SLUDGE FROM VARIOUS SURVEYS

Reference	Mercury Content (ppm)
Farrell and Salotto (45)	3.0 - 5.5
Nadkarni and Morrison (46)	9.06 - 84.3
Van Loon (47)	1 - 24
Van Loon (48)	3 - 13
Van Loon (49)	2 - 4
EPA (50)	0.6 - 43 (Average, 4.2)

5.3.3. **Miscellaneous Sources.** Spent fluorescent tubes and lamps, will most certainly be broken during disposal and the mercury vapour lost to the atmosphere. In 1978, approximately 4.5 tonnes of mercury were consumed in the manufacture of fluorescent tubes and lamps (Section 3.3). Assuming that 75% of the tubes and lamps replace broken ones, mercury emissions are 3 375 kg. These emissions are summarized in Table 26. (Provincial estimates have been determined based on population (34)).

TABLE 25 MERCURY EMISSIONS FROM SEWAGE SLUDGE INCINERATION, 1978

Province	Emissions (kg)
Ontario	116
Saskatchewan	3
British Columbia	5
TOTAL	124

TABLE 26 MERCURY EMISSIONS FROM FLUORESCENT TUBE BREAKAGE, 1978

Province	% of population	Emissions (kg)
Newfoundland	2.4	80
Prince Edward Island	0.5	17
Nova Scotia	3.6	122
New Brunswick	2.9	98
Quebec	27.2	915
Ontario	36.0	1 212
Manitoba	4.4	150
Saskatchewan	4.0	136
Alberta	8.0	269
British Columbia	10.7	363
Yukon - N.W.T.	0.3	13
TOTAL	100.0	3 375

Mercury is also lost from thermometers that are broken in hospitals. (Other sources of broken thermometers are unknown). Approximately 10% of the mercury will be emitted to the atmosphere, the remaining 90% to the sewer system. Assuming a thermometer contains approximately 2 g of mercury, 10 thermometers broken per hospital bed in a year, and a bed capacity in Canada of 201 413 (34), mercury emissions into the atmosphere are estimated to be 403 kg. Emissions from thermometer breakage in hospitals are summarized in Table 27.

TABLE 27 MERCURY EMISSIONS FROM THERMOMETER BREAKAGE, 1978

Province	Hospital Bed Capacity	Emissions (kg)
Newfoundland	3 853	8
Prince Edward Island	1 026	2
Nova Scotia	7 168	14
New Brunswick	5 789	12
Quebec	54 796	110
Ontario	68 563	137
Manitoba	9 082	18
Saskatchewan	9 635	19
Alberta	19 328	39
British Columbia	21 563	43
Yukon - N.W.T.	610	1
TOTAL	201 413	403

5.4 Base Metal Recovery

Trace amounts of mercury are found in virtually all minerals. Sulphide minerals such as sphalerite (ZnS), wurtzite (ZnS), chalcopyrite ($CuFeS_2$) and galena (PbS), have generally high levels of mercury. It has been estimated that at least 3 mg Hg is present per kilogram of these sulphidic minerals (52), based on the relative crustal abundance of the elements. Mercury content of zinc concentrates range from 2 ppm (Matagami area) through 20 ppm (Noranda area) up to 150 ppm (Val d'Or area). Mercury content in copper concentrates has been found to be less abundant, usually 1 - 10% of that found in zinc concentrate from any given mine (53, 54). There is no report of mercury having been detected in nickel ores.

Since mercury is associated mainly with sulphides, it remains in the concentrates and is lost mostly during the smelting process. This process consists of roasting and sintering steps to convert the sulphides to oxides, followed by pyrometallurgical or electrolytic treatment to recover the metals.

Emission data were obtained from various sources (55, 61) along with production of individual plants (57, 58, 59, 60). Emission factors varied for each metal,

from 1.25 kg/1000 tonnes for one zinc plant to 116.7 kg/1000 tonnes for another zinc plant. A range of emission factors are given in Table 28 by metal recovered. Total emissions from base metal recovery are given in Table 29.

TABLE 28 MERCURY EMISSION FACTORS FOR BASE METAL RECOVERY

Metal recovered	Emission factor (kg/1000 tonnes metal)
Zinc	1.25 - 116.67
Copper	15.63 - 53.49
Lead	1.58 - 2.20

TABLE 29 MERCURY EMISSIONS FROM BASE METAL RECOVERY, 1978

Region	Emissions (kg)
Eastern Canada	3 886
Western Canada	12 384
TOTAL	16 270

6 COMPARISON WITH 1970 MERCURY INVENTORY EMISSIONS

Total mercury emissions for each of the two years (1970 and 1978) for which inventories have been carried out, can only be compared with great difficulty because of different methodologies used to estimate mercury emissions from some of the contributing sectors. Such a comparison is easier however, on an individual sector basis and this is attempted briefly below.

A significant change in mercury emissions to the atmosphere has occurred as a result of a federal air pollution control regulation implemented in the chlor-alkali industry. Several plants previously using mercury cell processes shut down their operations while others complied with the regulation. This resulted in a 90% reduction in mercury emissions from that sector between 1970 and 1978. Previously identified as the primary source of mercury emissions in Canada, at 23.95 tonnes or 32.1% of the total in 1970, the chlor-alkali industry contributed 2.37 tonnes or 6% of total emissions in 1978. More recent information indicates that 1980 emissions of mercury are 1.24 tonne. This is a result of three additional companies closing their mercury-cell operations since 1978.

In the earlier inventory, mercury emissions from the combustion of petroleum products in Canada were estimated to be about 18 tonnes. This quantity, based on the best available information at the time, however, assumed one single value for the mercury content of all petroleum products. Recent and more reliable data now indicate that the original calculation overestimated mercury emissions from this source by almost an order of magnitude. For 1978, mercury emissions from the combustion of petroleum products have been estimated at 2.74 tonnes.

Emissions from the third most significant source of emissions in 1978, the application of paints, decreased by only 15% since 1970. However, changes have been made in the overall methodology. The assumption that only 25% of all mercury contained in paints emitted into the atmosphere differs from the previously used assumptions that interior and exterior paints contained 0.0013% and 0.013% mercury, respectively, and that only 50% of the mercury contained in exterior paints is emitted into the atmosphere while the other 50% entered the soil.

Absolute quantities of mercury emissions for some other sectors have also changed from 1970 to 1978 but here again the decreases or increases in emissions are more apparent than real because of better and more detailed information used in the

present report. For example, emissions from base metal recovery have doubled from those in the earlier report. This is largely due to the fact that 1978 data, considered more reliable, were obtained from actual source testing at the various smelters. Other sectors where better data have significantly altered results are: municipal incineration (-60%), wood combustion (-70%), sewage sludge incineration (-75%), instrumentation (+900%) and paint manufacturing (+200%).

Emissions from certain sectors have varied only because of a change in production or consumption. These areas include dental amalgams, fluorescent tube breakage and thermometer breakage.

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